Dr. Loew observed that chitine when treated with dilute sulphuric acid gives a reaction of sugar, the present substance gave no such reaction, and is therefore different from chitine and probably undescribed. It is probably closely allied to chitine but may contain a relatively larger amount of nitrogen.

Having collected a large quantity of the epidermis of the common brown mussel (*Modiola modiolus* L.) it was found to consist of purely horny matter, and dissolved with great ease in liquor potassæ. The conchioline which cements the layers of the shell is probably of a more refractory nature, but difficult to isolate without much labor except in very small quantities. If the fresh mussels be put in a box in a hot place the epidermis spontaneously scales off, and may be collected without trouble.

The horny shell of a gastropod which is distinguished by not becoming calcified (*Velutina coriacea* Pallas) was found to consist almost wholly of horny matter, with a trace of phosphate and a little carbonate of lime.

A large number of the shells of a brachiopod (*Rhynchonella psittacea* Ch.) were examined, and to our surprise yielded only a bare trace of phosphate of lime, 92 to 94 per cent of carbonate of lime, and the remainder consisted of horny matter. This raises a question as to the uniformity of the presence in other brachiopods (Lingula, Discina) of the large proportion of phosphate of lime, which has been detected in several analyses.

I have brought up this subject not so much for the value of the contribution now made to it (which is small), but rather to stimulate some of our chemical friends to work in a direction far more promising for science than some which of late have been more fashionable, and to call attention to our extreme ignorance of a great class of facts which, so to speak, lie daily before us demanding a solution.

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THE THEORY OF SEX AND SEXUAL GENESIS.

BY C. M. HOLLINGSWORTH.

(Continued from page 677, July number.)

THE view taken by Simpson seems to me altogether a just one, with regard to "the origin of those varieties of double hermaphrodites in which there is an actual coëxistence upon one or upon both sides of the body, or, in other words, in the same

segment of the sexual apparatus, of both the corresponding male and female organs. We can only refer all such instances to the laws which regulate the occasional production of local duplicities in different other organs of single bodies, and at the same time confess our present ignorance of what these laws are. We know that various individual muscles, nerves, &c, are not unfrequently found double, and that in the internal organs of the body examples of duplicity in individual viscera are occasionally, though rarely observed in the heart, tongue, trachea, œsophagus, intestinal canal, &c. In the several organs composing the reproductive apparatus, instances of similar duplicity would seem to be more common than among any other viscera." That they should thus be more common is what theory would indicate without assuming that they constitute a recurrence to an ancestral hermaphrodite form.

According to Darwin the sterility of hybrids is due mainly to an imperfect development of their reproductive organs. That there should be a greater derangement of the reproductive apparatus than of other parts, in an organism which is the product of a cross between two species, is what the theory of sex here proposed would indicate. For in the reproductive organs two redundant types have to be blended; and when a cross is effected between individuals of distinct species these two types represent parts that are functionally distributed among four distinct forms.

2. General principles pertaining to the formative conditions in the embryo also suffice to explain why it is that from a common embryonic type for the species each individual normally undergoes so pronounced a one-sided development, to ultimate in the adult characters of one or the other of the differentiated sexes, instead of developing equally and imperfectly the characters or organs of both. In considering this question these two facts should be borne in mind: 1. That where the same portion of primary tissue develops into one sexual organ in one of the sexes and into a different organ in the other sex, it is impossible for both organs to be developed in the same individual. 2. That the parts of the body of the forming embryo upon which the sexual organs are immediately dependent for the conditions of their evolution, considered as a nourishing apparatus, have not the capacity for supplying the conditions requisite to the full development of all the organs of both sexes, even if they were capable of all coëxisting in a fully developed state.

The determination to the development of the male or the female sexual gland is the essential or central fact in the whole sexual development of the individual. According to the latest views of embryologists, the ovary and the testicle in the higher animals originate from somewhat different parts of the layer of primitive generative cells which forms a thickening of a certain part of the walls of the peritoneal cavity on each side, when that cavity is formed. But since there is only a single mass of primitive cells from which either an ovary or a testicle takes its rise, we need not be particularly concerned here about whether it is the same part, or somewhat different parts, of the single mass that undergoes differential development, according as one or the other kind of glands is to be the outcome. In either case it is not difficult to understand why one kind of glands only and not both kinds is normally developed. If the conditions of development, as they immediately exist in the primitive generative cells, at the time when their development begins, are ever so little favorable to that course of development which will convert some of them into ova, they are by so much unfavorable to that course which would convert them into sperm-bearing cells; and *vice versa*. That is, the conditions that are suited to determine the development of one kind of generative cells are suited to arrest any tendency toward the development of the other kind. We are here dealing with the higher types of unisexual animals, in which there is a much more active circulation of the internal medium than in the lower animals. In the latter, germ-cells and sperm-cells are sometimes developed in near proximity to each other, but never, we may be perfectly certain, without an adequate differentiation of the conditions.

As there is a physiological, and therefore histological, difference in the stroma of the two kinds of sexual glands, analogous in kind to the difference between the two kinds of generative cells, the same statement will apply to the glands as well. Furthermore, it is probable that the same adjustment of the conditions on which cell-growth and cell-division respectively depend, which tends to initiate the development of one kind rather than the other of generative cells and sexual glands, is adapted to deflect the course of evolution of all the other accessory parts of the reproductive apparatus in the direction of the corresponding sexual type. Then the later stages of the one-sided development of

the individual in some of its sexual characters, and especially in what Hunter and Darwin have called the secondary sexual characters, is determined in great part by vital correlations between the parts thus developing and the sexual glands, established through the nervous system. This is clearly shown by the effect that is produced on the development of these parts by the removal of the sexual glands.

In monœcious and dicecious plants it is the reproductive member of the composite individual that undergoes a one-sided development. And the course of development is determined by a similar bias in the formative conditions—if not extending throughout the whole plant, at least in some manner initiated and maintained at the point from which the flower is developed. The peduncle and receptacle, one or both of which parts are common to all classes of flowers, and which are necessary to the development of the sexual organs proper, have their developmental capacities in every case adapted to their required functions; and their functions in plants in which the sexes are separate consist in giving support and transmitting nourishment to a set either of male or of female flowers, but not to sets of both. A receptacle, especially, which is required to bear organs of one sex only, will admit of being smaller and of more uniform structure than one which is required to perform the double function of bearing both stamens and pistils; and a difference of a similar kind must exist between the peduncles in the two cases. As the required structure of these parts in unisexual flowers is somewhat different for the two sexes, there is thus established not only a reduction in developmental capacity of these parts, but also a sort of structural dimorphism. And as these parts are not in themselves sexual, they tend, even when developing under conditions of an exactly medium character between those most favorable to the production of the male generative element and organs, on the one hand, and those most favorable to the production of the female parts, on the other hand, to assume the form suitable to one or the other alone.

In the higher animals that bias of the formative conditions which determines the sex is probably initiated, in most cases and under normal conditions, in the ovum at the time of its fertilization; or it may even depend on the constitution which one or the other of the combining cells has, previous to their union. But it

does not become sufficiently pronounced to produce any perceptible effect until a certain stage in the development of the embryo is reached. And the sex is no doubt subject to the controlling actions of external conditions for a time after the development begins, where the conditions of development, as they immediately affect the embryonic basis of the generative organs, can in this manner be considerably modified one way or the other.

In some of the lower animals, as will be shown farther on, the sex is subject to control at a very late stage in the life-history of the individual; and to a less extent this seems to be the case also with plants.

Causes Determining Sex.—Since germ-cells are very large and sperm-cells are small, it may at once be inferred that where they are formed in different parts of the organism, the parts in which germ-cells or their producing organs are formed must be parts in which the conditions are especially favorable to nutrition; and that the parts in which sperm-cells or their producing organs are formed, must be relatively unfavorable to nutrition and favorable to cell-division. Observation shows this to be the case; and from the causes thus indicated as determining the development of one or the other or of the two kinds of generative cells or organs, in different parts of the same organism, some of the causes may be inferred which act to determine the sex of the individual, where the sexes are separate, and the truth of the inference tested by the results of observation and experiment. There is evidence, however, that the sex of the individual may also be determined by the state of maturity at which the ovum has arrived before it is impregnated; and the true theory of sex must be capable of explaining this fact.

I will now give such evidence, of various kinds, as I have been able to obtain on the causes which determine the sex, for the purpose of showing its agreement with the theory of sex given in the earlier parts of this article. The hypothesis, it should be remembered, is, that it is a *relative* preponderance of the conditions on which cell-growth depends, or of the conditions on which cell-division depends, which causes the formation of the female or male generative organs or determines the sex of the individual. If, therefore, the conditions on which either factor of the developmental process depends remain constant, the requisite preponderance, one way or the other, may still result

from variations in the conditions of the other factor. It should be remembered further that both factors are required to be present in the developmental process in the formative or initial stage of the development of all organs, the reproductive organs included.

In the higher plants this initial part of the development is generally effected at or within a very short portion of the extremity of each axis. But whether it is confined to this part or not, it is universally the case in "perfect" flowers that the pistils occupy the central position, with the stamens disposed around them. And that the central position is the one most favorable to cell-growth, and the outer position the one most favorable to cell-division, is shown by the fact that in the pith of exogenous plants the central cells are the largest—the cells decreasing in size from the center outward. The conditions on which this difference depends are no doubt complex; but it is probably due mainly to the freer access of oxygen to the outer cells; since it has been shown that the oxygen consumed in these forming parts of plants is derived directly from the surrounding air, and is not brought to them in the sap from other parts; while the nitrogenous proximate compounds that enter into the formation of the extending axis are derived mainly from other parts, and the whole supply of the lower compounds of nitrogen necessary to the growth of the plant is taken in through the roots. The access of oxygen is required both for cell-growth and cell-division. But it is mainly to its nitrogenous constituents that protoplasm owes its plasticity or instability as to state of physical aggregation; and these constituents are also chemically less stable than the other constituents. The more active respiratory changes induced in the outer cells would, therefore, have the effect of causing them to divide more rapidly than the central cells; or of preventing them from growing to so great a size as that attained to by the central cells before undergoing division.

In monœcious plants it is the female flower, as a whole, that develops from a part in which the conditions of cell-growth predominate, and the male flower that develops from a part in which the conditions of cell-division predominate. In monœcious exogens, as hickory, walnut, &c., we find the female or pistillate flowers on a terminal peduncle, while the catkins of male or staminate flowers are produced from lateral buds of the same

branch. In Ricinus, the castor-oil plant, the flowers are in a short panicle, with the female flowers at the terminus of the thick main axis, and the much more numerous male flowers borne in thick bunches on small lateral branches of the main axis. In some endogens these relative positions are reversed, but only where the conditions of nutrition in the parts are also reversed. Thus in maize the staminate spikes or tassel form the terminal branches of the main stem; but they are far removed by a long and slender portion of the stem from the assimilative organs—the leaves—of the plant; while the spike of pistillate flowers that forms the ear terminates a short and thick lateral branch produced in the axil of a large leaf in the middle part of the stalk. So likewise where both male and female flowers are borne laterally on a long and tapering spike, as in Stillingia, the staminate flowers occupy or form the upper part, and the pistillate the lower part of the spike.

In the Compositæ it is generally the marginal flowers of the head that are pistillate, while the thickly-crowded flowers of the central part of the head, which are thus less favorably situated as regards nutrition, are staminate only, or in some cases perfect. The same distribution obtains also in the Umbelliferæ. Here it is often the case that the same umbel or umbellet contains the three kinds of flowers, pistillate, perfect and staminate, clearly arranged according to the conditions of nutrition. Thus in sweet cicely (*Osmorrhiza longistylus*) and parsnip (*Pastinaca sativa*) the flowers are in compound umbels, and as regards the three kinds just mentioned, have the following arrangement: The central umbellets of the compound umbel are the smallest of all and often bear small staminate flowers only. Umbellets that are neither central nor peripheral, but intermediate in position, are also intermediate in size, and generally bear small, staminate flowers in their central parts and larger, perfect flowers in their outer parts. The outer or peripheral umbellets of the compound umbel are the largest and bear small, staminate flowers in their central parts and larger, perfect and pistillate flowers in their outer parts. Here we have a regular gradation from wholly male to wholly female flowers, with increase in the size of all the accessory parts, which difference in size must result from difference in the conditions of nutrition, or growth.

While studying the inflorescence of the wild parsnip it oc-

curred to me that since in this plant the receptacle of the umbellet is somewhat projecting in the center, and since the apex of the axis in growing plants is generally the point of most rapid growth, it might be the case that this central point of the receptacle would in some instances bear fertile flowers when parts further out and intermediate in position would not. And on more careful examination I found in many instances a single pistillate flower occupying this position, but showing this remarkable peculiarity, that it was sessile upon the apex of the receptacle; and from the considerable number of flowers in the umbellet, twenty to thirty, and the fact that all the others were carried out beyond this one, by their extended pedicels, so as to partially conceal it, I had previously overlooked it in making out the distribution of male, perfect and female flowers on the umbellet.

As has just been shown, there is a strict correlation between the size of the umbellets of a compound umbel and the sex of the flowers they bear, the smallest umbellets bearing male and the largest predominantly female flowers. In Indian turnip (*Arisæma triphyllum*) there is a similar correlation between size and sex for the whole plant, the largest plants being females, the smallest (that produce flowers) males, and many of the intermediate ones monœcious. So striking is this the case that I found that when the plants are in bloom the sex can be inferred, with a great degree of certainty, from the comparative size of the plants alone. At this time the spathe so incloses the spadix on which the flowers are borne, that it cannot be determined by direct observation whether a plant bears male or female flowers, or both, except by opening the spathe. The plants reproduce by buds from corms, and by bulbs dropped from the receptacle, and are thus found most frequently in groups, the plants in the same group varying greatly in size. The large buds from the older corms produce the largest plants, and the bulbs of the previous year the smallest; these latter, however, do not produce flower-stalks the first year.

To prove the correlation between sex and size, I made examinations at one time of 213 plants, and at another of 137 plants, while they were in bloom. An inference was first made as to the probable sex of each plant, judging from its size as compared with the others of the same group, or as compared with the average size for the locality, each plant being pronounced either

male or female, and thus no attempt being made to tell from the size which were monœcious. Then by opening the spathe the inference was found to be either right or wrong, or partly right and partly wrong, and was so recorded. Of the 213 plants seventy-four were judged, from their size, to be females, which proved on examination to be such, and ninty-six were judged to be males, which proved to be such; seven were judged to be females and ten to be males, which proved to be monœcious; thirteen, mostly of medium size, were judged to be females which proved to be males; and thirteen, mostly of medium size, were judged to be males which proved to be females. Of the 137 plants fifty-seven were rightly judged to be males, and sixty-four rightly judged to be females; so that there were only sixteen out of the whole number whose sex was wrongly inferred from the size. Thus in the great majority of cases the sex was correctly inferred from the size of the plants; and in nearly all the cases where the inference was wrong the plants were of medium size, in which case there would necessarily be much uncertainty in attempting to determine the sex in this way.

Here we have, I think, very conclusive evidence that the female sex is determined by a relative predominance of the conditions of nutrition or cell-growth over the conditions of differentiation or cell-division, as compared with the correlation of these conditions in the production of the male sex. All the external conditions of development, comprising temperature, the supply of oxygen and carbon dioxide in the air, and the supply of water and other matters in the soil, are precisely the same for all the plants of each group. The only difference is, that the larger corms contain a greater quantity than the smaller ones of elaborated and stored-up proximate compounds to be organized about a single axis of growth. And from the larger aggregations of nutritive matter female plants are developed; while from the smaller aggregations male plants are developed.

The observations or experiments of Knight furnish the most conclusive evidence we have of the nature of the external conditions which act to determine the sex in plants. He found "that several kinds of monœcious plants can be made to produce solely male or solely female flowers, by regulating the quantity of light and heat under which they are grown. If the heat be excessive, compared with the quantity of light which the plant receives,

male flowers only appear; but if light be in excess, female flowers alone will be produced" (Carpenter, Comp. Physiol., 1851, p. 979). According to Sachs' account of the conditions on which cell-growth and cell-division respectively depend, these results obtained by Knight agree with the theory of sex here proposed. "In the case of the buds of the higher plants their reservoirs of reserve material are the bulbs, tubers, rhizomes, parts of the stem, cotyledons and endosperm; after the complete exhaustion of these, growth ceases in the dark but continues in the light, because the assimilating organs can then produce new material. This relation of growth, which is connected with cell-division, to assimilation, is especially clear in algæ of simple structure, which assimilate in the day-time under the influence of light, while cell-division proceeds exclusively, or at least chiefly, at night. The swarmspores are also formed at night, but swarm only with the access of daylight. In some Fungi, also, the splitting up of the protoplasm in the sporangium into a number of spores takes place only in the night, the spores being thrown out on the access of light. While, therefore, in the larger and more highly organized plants assimilation and the construction of new cells out of the assimilated substances is carried on in different parts but at the same time, in small transparent plants, in which the parts where these functions are effected are not surrounded by opaque envelopes, they take place at different times" (Botany, p. 753). The conditions on which cell-division depends are no doubt present both in light and darkness, but in the light there is a predominance of the conditions of growth.

Speaking of the segmentation of the animal ovum, Stricker says: "In the fecundated egg the spermatozoa must be regarded as the agents from which the first excitation proceeds. There can be no doubt, also, that in the act of fission a high temperature plays an important part" (Manual of Histol., p. 46). This also accords with the interpretation of the results of Knight's experiments required by the theory of sex here proposed.

There is evidence of a similar kind to that now given with respect to plants, showing that in animals likewise the sex may be determined or controlled to a greater or less extent by conditions of nutrition. "According to Girou, female domestic animals bear more females when well nourished and left in repose than when much worked and on spare diet" (Allen Thomson,

Todd's Cyclop., art. Generation). But experiments that have been made on the larvæ of butterflies and moths furnish the most conclusive evidence that has yet been obtained of the determination of sex in animals by conditions of nutrition.

In the AM. NATURALIST for March, 1873, an account is given by Mrs. Mary Treat of experiments on this point, both with butterflies and moths. Larvæ that were shut up in paper boxes soon after the last molt and deprived of food, nearly all developed into males; while larvæ of the same lot that were highly fed on good food as long as they would eat, nearly all developed into females. Similar experiments have been made by Gentry with moths, and with the same results; and he adds the following facts which came under his notice in the course of his observations and experiments: 1. That males are the invariable result when the larvæ are fed on diseased or innutritious food; 2. That in the fall, when the leaves have not their usual amount of sap, males are generally produced; 3. That more males are produced late in the season than females; 4. That the sexes in early life cannot be distinguished, the change being brought about late in life by the conditions of nutrition" (Abstract in *Pop. Sci. Mon.*, April, 1874, of a paper communicated to the Phil. Acad. of Sci.). In the case of the well-fed larvæ there is a greater accumulation of nutritive material to be reorganized in the metamorphosis than there is in the case of the ill-fed larvæ; while the other conditions of development, temperature and the supply of oxygen are the same for both.

The effect which the time of the impregnation of the ovum has in determining sex has yet to be considered in its bearings on the foregoing theory of sex. Girou found that if the female flowers of diœcious plants be fertilized as soon as they are fit to receive the pollen, the seed resulting produced mainly female plants; and that if the fertilization be deferred to as late period as possible, the seeds resulting produce mainly male plants. "Starting from this idea, and supposing that the complete maturity of an ovum might be very favorable to the production of the male sex, and inversely, M. Thury, of Geneva (1863), caused cows to be impregnated, sometimes at the beginning, sometimes at the end of the rutting period. In the first case he obtained female calves; in the second male calves. The experiment was repeated by a Swiss agriculturalist, M. Cornaz, who twenty-nine times in twen-

ty-nine cases, succeeded in producing at will such or such a sex" (Letourneau, Biology, p. 312). Experiments on the effect of late fertilization of the eggs of birds had previously been made by Knight, "which," he states, "to have been frequently repeated," and which gave similar results. "When the female was kept without intercourse with the male up to nearly the time for laying, so that the eggs had advanced very far in their development at the time of fertilization, the proportion of males among the offspring was very large, commonly about six out of seven" (Carpenter, *op. cit.*, p. 979).

In the theoretical interpretation of these results, the important fact to be noted is, that the mature ovum, even without fertilization, generally undergoes segmentation in an imperfect manner before its death and dissolution takes place. Thus from the beginning of the period during which the ovum is capable of being impregnated to the time when segmentation begins, the protoplasmic mass of the ovum undergoes a gradual change from a more stable to a less stable state of aggregation as a mass. This change is no doubt accelerated by the access of the sperm-cell, at whatever time fertilization may take place. Still if fertilization takes place at a very early period, the interval of time which will follow before segmentation begins will be greater than it will when fertilization takes place at a later period. And there is evidence that during that interval the sperm-cell tends to become assimilated in its constitution to the germ-cell, and therefore, by hypothesis, to have its specific capacity or function of exciting cell-division to some extent weakened. Recent investigations have shown that the act of impregnation consists in the formation of a male "pronucleus," derived from the impregnating sperm-cell, which fuses with the female "pronucleus" of the germ-cell to constitute the single nucleus of the fertile ovum. And Hertwig points out, "that considerable difference may be observed in the occurrences which succeed impregnation, according to the relative period at which this takes place. When, in Asterias, the impregnation is effected about an hour after the egg is laid, and previously to the formation of the polar-cells, the male pronucleus appears at first to exert but little influence on the protoplasm, but after the formation of the second polar-cell the radial striæ around it become very marked, and the pronucleus rapidly grows in size. When it finally unites with the

female pronucleus it is equal in size to the latter. In the case when the impregnation is deferred for four hours, the male pronucleus never becomes so large as the female pronucleus. With reference to the effect of the time at which impregnation takes place, Asterias would seem to serve as a type" (Balfour, Comp. Embryol., Vol. 1, p. 68).

Thus when impregnation takes place at a very early period, since the ovum in its own independent course of development has not yet reached the segmenting stage, the immediate effect of the union of the female and male elements is a modification of the male element by which it is to some extent assimilated in character to the female element. In consequence there is established in the fertilized ovum at the outset a relative preponderance of the factor of cell-growth, in its developmental tendencies; and this, by the theory, determines to the production of the female sex. But where impregnation takes place at a late period, when the ovum in its development has reached the segmenting stage, its modifying action on the male element before the union is completed is less; and in consequence there is established in the fertilized ovum at the outset a preponderance of the factor of cell-division, which the male element represents; and this, by the theory, determines to the production of the male sex.

It appears, therefore, that the theory of sex and sexual genesis that is here proposed, affords a reasonable explanation of the observed effects of the time of impregnation in determining sex. And so far as all the known causes on which the determination of sex depends are incapable of being equally well explained on any other theory, they may be taken as giving support to this theory.

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THE CONDYLARTHRA.

BY E. D. COPE.

IN a paper on the homologies and origin of the molar teeth of the Mammalia Educabilia, published in March, 1874,[1] I ven-

[1] Journal of the Academy of Natural Sciences of Philadelphia. The language which I used is as follows: "I trust that I have made it sufficiently obvious that the primitive genera of this division of mammals [Mammalia Educabilia = Unguiculata and Ungulata sensu latâ] must have been bunodonts with pentadactyl plantigrade feet."

The nearest approaches to a similar anticipation on the part of other naturalists which I have been able to find, refer to the number of toes only, and are of restricted